Chapter I. Description. Rivers. *The Malprabha.*

is about 300 feet deep includes an upper or south-western half not more than fifty yards wide, and a lower half which is broader and with lower banks. The upper or south-western half is so narrow that, even in moderate floods, not an inch of margin is left between the water and the vertical walls on either side. During great floods the water rises thirty to forty feet in the gorge, and rushes with mighty force, forming pot-holes of great size and depth, which at every new-moon in the fair season, when the water is low, are largely resorted to by Hindu devotees. In its lower or northern half, the gorge widens considerably, and the sides decrease in height, till the quartzite beds die out in a level flat which stretches for some distance to the north-east.

At every village along the bank of the river, right down in the bed of the stream, is a small square temple containing a *ling*, and in front of the small low door is almost always an image of Basav in the form of the sacred bull. The banks vary much in character; in some parts they rise sharply from the water's edge, in others they have a gentle slope, and in a few places the river runs almost on a level with the country round. Near Manoli the Malprabha receives from the left the Benákatti, a stream which rising in the trap hills near Sategiri, has a southerly course of about twenty miles. Besides the Benákatti, though both from the north and the south many small streams fall into the Malprabha, it has no important feeders. At Sogal, ten miles west of the Manoli gorge, a stream which after a southerly course of about five miles falls into the Malprabha near Kungari, runs southward through a depression in the quartzite boundary ridge, and forms a very picturesque waterfall in a semicircle cut into the hard quartzite conglomerate. The fall is over a sheer rock fifty to sixty feet high. Above the principal fall are two minor falls, which, with an old temple and a group of trees, form a very pretty scene. The chief ferries on the Malprabha are at Jámboti, Khánápur, Mugutkhán-Hubli, Turmuri, Sangoli, Virápur, Yakundi, and Manoli.

Besides these three main rivers, where, in the south-west, the district stretches to the crest of the Sahyádris, the Mahádáyi, a feeder of the Goa river, and the Tilári, a small river near the Rám pass, drain westward through clefts in the crest of the Sahyádris.

Water.

Except the east of the plain country, which is generally badly off for water, the water-supply is plentiful. In Gokák, the plain from four to six miles wide, between the Ghatprabha and the chain of hills on which Mamdápur stands, is formed of rich black soil everywhere of good depth. The land is capable of yielding the richest crops if only there was water. But the rainfall is so uncertain that only once in three years is there a fair harvest. The east of Parasgad is subject to droughts followed in the hot months by a failure of drinking water. In other parts artificial ponds and reservoirs hold drinking water during most of the year.

Geology.

Geologically[1] the district forms three great belts. In the south

used it ever since. The river at this spot is supposed to have great cleansing power. Memoir Geological Survey, XII. Part I. 99.

[1] The geological sketch of the district has been compiled from Mr. R. B. Foote's Memoir on the Geological Features of the Southern Marátha Country and Adjacent Districts. Geological Survey of India, XII. Part I. of 1877.

Chapter I. Description. Geology.

is a narrow strip of gneissic rock; in the centre are quartzite and limestone partly overlaid by two great bands of trap; and in the north and west are trap and iron-clay. The earliest traceable event in the history of the Belgaum rocks is the making of the stratified schist. This process was probably continued at intervals through long periods. The schist beds were then forced up, broken, and their character changed by a volcanic eruption, of which certain old highly crystalline trap dykes are a record. After remaining as land through long ages the gneissic rocks sank, were worn by the sea, and as they sank still lower, sandstones and limestones were formed from their ruins and laid over them. Another volcanic eruption forced the sandstones and limestones above sea level, changed their character, and twisted and broke them. For long they continued as land, weathering into hills and valleys, the rivers widening in places into small lakes where cross ridges checked their flow. Next, from the north-west, lava flows rolled over this rugged country, filling valleys and leaving swelling downs and shallow hollows. Of these flows only a few reached the east of the district, but towards the west at least eight great flows came at intervals and lay one over the other. Since the flow of lava ceased the general lie of the country has not changed. The surface has been greatly worn, but the wearing forces have apparently entirely been air-forces, sun, rain, and wind. Though over large areas it has now disappeared the iron-clay capping of Bágedgudd near Gokák shows that the latest lava flow spread at least as far east as the centre of the district. The rivers have long forced their way east through the hardest hills. But rocks formed under fresh water and gravel and shingle beds on river banks, sixty to eighty feet above present flood levels, show that at some period after the latest outflow of lava the country was in places covered with lakes. Since their outflow air and water have changed the latest lava beds into an iron-clay rock that caps most of the higher hills, and in the plains the traps have weathered into red soil, and traps sandstones and gneiss mixed with vegetable matter have weathered into black soil. The rocks are almost entirely without organic remains. Almost the only signs of plant or of animal life are in recent alluvia, where, besides shells, the bones of a wild ox and of an extinct species of rhinoceros have been found.

Beginning from the surface the succession of the geological formations is:

Post Tertiary or Recent:
7. Sub-aërial Formations and Soils.
6. Alluvia.

Later Tertiary:
5. Bone-bearing Deposits.

Upper Secondary:
4. Deccan Trap and Associated Formations
(*b*) Iron-clay (laterite) Formations. (*a*) Intertrappean Lake Beds.
3. Infra-trappean Formations, Lameta Beds.
2. Kaládgi Series of Sandstones and Quartzites (Sub-metamorphic).

Azoic:
1. Gneissic (Metamorphic) Series with Associated Intrusive Rocks.

For descriptive purposes the different formations come most conveniently in their true geological or ascending order.

Within Belgaum limits the Gneissic Rocks form a belt that stretches across the south of the district varying in breadth from two to six miles. Besides in this belt gneissic rocks appear as inliers in some cases among sandstones and quartzites, in other cases among trap.[1] It has not been settled whether all the gneissic rocks belong to the same geological age. Full inquiry will probably show that they admit of subdivision and classification. The series includes a very considerable variety of rocks, schistose or granitoid, separated into great sharply-defined bands, which, in many cases, may be traced across the country from the southern boundary of the younger traps, across Dhárwár to the Tungbhadra and away into Bellári and North Maisur.

West of the Dhárwár-Belgaum road the gneiss is greatly obscured by lateritic or lithomargic surface deposits. Beyond these, near Khánápur, about fifteen miles south of Belgaum, is a broad belt of granitoid gneiss, the bedding of which is doubtful. Further west is a great development of very schistose chiefly micaceous gneiss with some very thick beds of crystalline limestone, the strike of which is difficult to indicate as the beds roll at low angles. These beds show much the same position in the several sections at Bhimgad and in the Tilári ravine. The rocks met with in the gneissic series are divided into two great groups, the granitoid, which are highly crystalline and massive, and the schistose, which are less crystalline and often highly foliated and distinctly bedded. The schistose areas differ from the granitoid areas by the much greater smoothness of their surface. Even when they form hills the hills are in most cases gently rounded, the scenery is commonplace and tame, and there is a want of vegetation. A band of granitoid gneiss crossing the Malprabha, and numerous dykes having a north-east to south-west course, appear in the Kathárigad valley, about sixteen miles west of Torgal. Another granitoid band forms some noticeable hills at Ganibáil, twelve miles south of Belgaum, and passes south through Khánápur to the Nandgad hills. Besides, at Saundatti, a very broad band of schistose rocks appears in the upper valley of the Malprabha at Báil Hongal, about ten miles west of the Kathárigad granitoid band, and stretches south-west within a few miles of Khánápur, where it joins the most westerly band of granitoid gneiss.

The commonest type of granitoid gneiss is a more or less porphyritic rock consisting of quartz, felspar, and hornblende in varying proportions. The felspar very frequently predominates. As a rule the granitoid varieties are not distinctly bedded. The transition from the highly crystalline massive form to distinctly bedded and even schistose rocks is often seen near the boundaries of granitoid areas. The granitoid gneiss in those cases shows a broadly banded structure, the bands being parallel to the true

[1] There are twelve chief inliers: the Kathárigad inlier thirty miles east of Belgaum; the Halki and Budnur inlier north of the Belgaum-Kaládgi road; west of these are the Vannur and Páchápur inliers; to the north of these are three other inliers at Kelvi, Mamdápur, and Gokák; further south are two inliers in the Belgaum valley; and west of Belgaum close to Patna two small inliers show through the Deccan trap.

Chapter I. Description. Geology. *Gneissic Rocks.*

foliation of the less altered rocks, and being in fact the true layers of original deposition.

The two chief varieties of schist are micaceous and hæmatitè. The micaceous schists, though uncommon in the east, are seen in vast thickness in the ravines of the Mahádáyi and Tilári and in the scarps south of the Párvár and Rám passes. Of hæmatite schists numerous beds are found in the upper valley of the Malprabha in the Báil Hongal schistose band where they form conspicuous ridges among the softer schistose rocks. Their silicious laminæ are generally very fine-grained, and are often as semi-vitreous in texture as true quartzites. Their colour varies from nearly white to bright red or even dull brown. The true foliation or bedding of the rock is almost always perfectly preserved. They are poor in iron, and rarely show much of the red staining, though they are frequently jaspideous in texture. The country is covered with their debris to a remarkable extent. Minute and small quantities of gold are found associated with hæmatite beds in some of the streamlets about Báil Hongal and Belovádi.

Associated with the schistose members of the gneissic series are beds of crystalline limestone. On one of the most conspicuous masses of this limestone stands Bhimgad fort, about twenty-five miles south-west of Belgaum. From the north side of the great Mahádáyi ravine, looking over the scarp formed by the edge of the trap area, Bhimgad, with neighbouring limestone peaks and several huge masses which have slipped into the valley, forms a wild and most beautiful scene. The dolomite beds extend southward from Bhimgad across the Kel or Talevádi pass and up the northern slope of Darshindongar the highest hill in this part of the Sahyádris. Here, as at Bhimgad, the limestone is a light gray sacharoid magnesian with numerous quartz laminæ.[1] Near the east gate of Bhimgad a large quantity of dark blackish brown powder is found on the surface of the dolomite from which it has evidently weathered. The face of the limestone which is here greatly hid by vegetation is darker than in the main mass of the mountain. There are three other chief instances of crystalline limestones. A gray crystalline limestone underlying the hæmatite-schist bed which forms the crest of the ridge south of Báil Hongal in the upper valley of the Malprabha; a small outcrop of very silicious gray limestone which forms two small inliers four miles east of Nesargi on the Belgaum-Kaládgi road; and to the east of Gudganhatti, six miles north-east of Nesargi, a very considerable bed of gray limestone associated with argillaceous and micaceous schists.

Of trap, granite, and quartz the three chief foreign dykes or reefs that cross the South-Marátha gneiss, the only reefs of any size within Belgaum limits, are trap dykes. A numerous set of dykes, with a north-east to south-west course, cross the gneiss inlier in the Kathárigad hills. The largest of this group is a very broad dyke which, rising from the black soil three miles north-west of Behvur,

[1] An analysis of the dolomite showed water and organic matter 4·0; carbonate of lime 56·4; carbonate of magnesia 34·8; oxide of iron with a little alumina and manganese 3·6; insoluble 2·2.

Gneissic Rocks.

runs for about eight miles, till it joins another very large dyke. Beyond this dyke it does not reappear, or is again immediately lost under the alluvium of the Krishna at Mudukop. An intrusion of dioritic trap, surrounded by a vast unbroken spread of cotton soil, occurs at Asmatti, about twelve miles east of Parasgad, and forms a long low rocky hill. To the north and south the ridge dies away rapidly under the cotton soil, but groups of large masses stand out at intervals showing that it stretches north-west and south-east for about three miles with a width of two-thirds to three-quarters of a mile.

Kaládgi Series.

A great series of quartzite, sandstone, and limestone rocks, in many respects closely resembling the Kadapah series,[1] forms a well marked basin, lying mainly between the banks of the Krishna and the Malprabha rivers. In geological sequence these rocks are next in age to the gneissic series on which they directly and unconformably rest. Their broken ridges of varied outline, relieve the dullness of the central and eastern plain, but their barren sandy soil is unfavourable to vegetation. Within Belgaum limits the rocks that belong to the Kaládgi series are of two leading varieties, quartzites and limestones. The quartzites are found in a line that runs from Daddi in the west to Rámdurg in the east, about two-thirds from the north of the district. The limestones, which are of later formation than the quartzites, occur in an inner basin in the eastern centre of the district, a space about fifteen miles from north to south and about thirty miles from east to west. Beyond these limits, quartzite and limestone rocks appear in many parts of the district both as outliers resting on older rocks, and as inliers, exposed by denudation within the area of younger rocks. The chief of the inliers are to the west, the Mángaon inlier in the upper valley of the Harankáshi, the Shengaon and Assangaon inliers in the valleys of the Vedganga and Dudhganga in Kolhápur, and a group of large and small inliers on the south bank of the Ghatprabha near Yádvád about nine miles south-west of Mudhol. Of the outliers one of some importance caps the Parasgad hill and two small ones occur a little to the north-east.

The series, as a whole, where disturbed, is decidedly metamorphic. The disturbed parts lie within the Kaládgi basin, the undisturbed parts are, with few exceptions, the western outliers. As no trace of any organism has been detected the series may for the present be regarded as lifeless or azoic.

The whole series may be subdivided as follows in descending order:

	Feet.
B.—*Upper Kaládgi Series.*	
6. Shales Limestones and Hæmatite Schists ...	2000
5. Quartzites with local Conglomerates and Breccias ...	1200-1800
A.—*Lower Kaládgi Series.*	
4. Limestones Clays and Shales	5000-6000
3. Sandstones and Shales	3000-5000
2. Silicious Limestones and Hornstone or cherty Breccias	
1. Quartzites Conglomerates and Sandstones	

[1] This series takes its name from Kadapah a British district in the Madras Presidency between 13° 12′ and 16° 19′ north latitude and 77° 52′ and 79° 48′ east longitude.

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Kaládgi Series.

The total thickness of the series is not clearly known. Near Kaládgi the depth is not less than 10,000 to 15,000 feet, and in the west, among the Sahyádris, where all the rocks apparently belong to the lower series, the thickness is not less than 1000 feet.

Rocks belonging to the upper series are found only over small areas in the east of the district. The chief places are to the west of Lokápur and to the west and east of Yádvád. Of the upper series of rocks the limestones of the higher portion are found only in the east. This limestone tract is on the eastern boundary about fifteen miles from north to south, from about five miles south of Mudhol to about ten miles north of Rámdurg. It stretches in a broken belt about thirty miles north-west into the trap country, narrowing till it ends near Beshati on the right bank of the Ghatprabha about twenty miles below Gokák. The remaining rocks of this series belong to the quartzites and shales, the lowest section of the Lower Kaládgi Series. These form an irregular winding belt, which, beginning about five miles on either side of Rámdurg in the east, stretches first north-west to Gokák, and then south-west to Daddi in a band ten to twenty miles broad.

The base of the Kaládgi series rests on the gneissic rocks whose surface was so uneven that in places the basement beds of the quartzites and sandstones may be seen lapping round prominences rising from the surface of the older rocks. The silicious rocks of the lowest Kaládgi sections are entirely of materials taken from worn gneiss. The two sections of the Lower Kaládgi series may be further divided as follows:

II. 4. Limestones Clays and Shales.
3. Sandstones and Shales.
I. 2. Silicious Limestones and Hornstone Breccias.
1. Quartzites Conglomerates and Sandstones.

Lower Kaládgi Series.

The three lowest subdivisions are so closely connected that they may be best taken together in the same section. The basement beds of the Lower Kaládgi Series consist of conglomerates, grits, sandstones, and quartzites of great aggregate thickness. There are occasional beds of shale or shaley flags, and in one place several beds of hæmatite schists. All the outliers belong to this section of the series. In the rocks of the series there is great local diversity of texture and colour. At the same time the relative characters of the more important subdivisions are to a great extent constant, and the gradual decrease in coarseness of texture from below upwards holds good almost everywhere. Resting upon the basement beds, in the east and south of the basin, are found beds of intensely silicious limestone, which in many places pass or seem to pass into very characteristic hornstone or cherty breccias. Resting upon these come in most parts of the basin the clays, shales, and limestones that are grouped together in sub-section 4. In the south and west of the basin an important group of sandstones and shales appears between the breccia beds and the base of sub-section 4. But the imperfect character of the local sections and the presence of a broad band of Deccan trap combine to make the relations of the beds obscure and doubtful. As a rule the rocks of this section lie somewhat upturned,

Lower Kaládgi Series.

the outer boundary scarps forming a true basement edge. Within the basin, they are usually waving, but in some places are horizontal, and in others are much disturbed and crumpled. In the western outliers the conglomerates and sandstones are almost undisturbed and show a minimum of metamorphic action.

The colour of the conglomerates and lower grits varies much more than the colour of the higher beds. Among the conglomerates the chief shades are purplish-gray and dark purple, pinkish-gray from the decomposed granite-gneiss, whitish-gray where there are many quartz pebbles, and much light reddish-brown. The shaley beds are usually drab or pale ashy-gray. Near the jaspery hæmatite schists of the gneiss the conglomerates are in many places almost entirely composed of rolled or angular fragments of the jaspery hæmatite of all colours peculiar to those beds.

The cherty breccia beds, which are peculiar features of the Kaládgi basin, by weathering into disconnected masses, obscure the relations between the underlying and the overlying rocks. The position and the relations to the great bands of very silicious limestone, which occur to the north and north-west of Manoli, seem to show that the breccias are altered silicious limestone. The change from limestone to breccia was probably caused by highly acidulated water soaking in and carrying away so much chalky matter that the cherty skeleton was broken by the weight of the overlying rocks. Subsequent infiltration of flinty chalky and iron-clay matter formed the crushed chert into a breccia with variable cement. The greater part of this change probably took place during the period of volcanic energy which produced the Deccan trap.

The following details of sections show the character of the Kaládgi quartzite hills in different parts of the district:

Lower Kaládgi Quartzites.

At Gokák, the great series of pebbly and gritty quartzites are remarkably uniform in colour and texture. Drab to reddish brown are the leading colours. The best section is in the gorge of the river just below the fall. Here the exposed thickness of quartzites and conglomerates cannot be much less than 400 feet, of which more than 300 are exposed in the cliff on the north side of the falls.[1] The curved lines showing the outcrops of the quartzite beds are very conspicuous on the face of the cliff. For some distance above the fall the water[2] runs at a great pace, and in consequence has worn in the very hard quartzite many fine specimens of pot-holes some beds of which both here and in many neighbouring sections are typical waxy quartzites showing beautifully preserved rippling.

[1] The cliffs flanking the right side of the river below were found by Captain Newbold rent by nearly vertical fissures from summit to base. Two of the largest, with a direction of east-south-east, were crossed nearly at right angles by minor cracks, which thus insulated portions of the rock. The bases of these tottering pinnacles were often undermined by the action of the water and the mass tumbled headlong into the stream. Geological Papers on Western India, 355.

[2] At Konur, about two miles and a half above the Gokák falls, a tumblerful of the turbid water deposited one-fiftieth of its bulk of a fine reddish clay, not calcareous. The pebbles brought down were chiefly quartz, granite, and hypogene schist, with a few calcedonies; the sand contained grains of magnetic iron. Geological Papers on Western India, 355.

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Lower Kaládgi Quartzites.

A large fissure[1] in the cliff which forms the south side of the gorge, is really composed of joint fissures much enlarged by the partial sliding forward of the rocky masses.

In spite of the hardness of the rock, the gorge is cut fully a mile back from the general scarp of the Gokák hills. This scarp must have had something of its present shape before the outpouring of the Deccan trap. And there can be little doubt that these quartzite rocks were more worn away before than they have been since the outpouring of the trap flows.

Two small but very marked outliers of the basement conglomerate beds cap isolated and almost conical schistose hills, one on either side of the Ghatprabha where it issues from the gorge below the falls. These conglomerate beds form sharply scarped table tops to two hills of hornblendic and micaceous schist. The larger hill, which rises more than 600 feet above Gokák, overlooks a great part of the quartzite plateau which stretches away far to the south-west.

Very beautiful quartzite cliffs, whose bright red contrasts splendidly with the encircling green brushwood, occur in the valley of the Márkándeya, two miles south-west of Gokák, and especially in a great ravine that opens into the valley from the Karabgatti plateau on the south. Round many parts of the Gokák scarp the edges of the conglomerate beds form wall-like cliffs, and occasionally from the more rapid weathering of the schistose beds in the underlying gneiss, fallen quartzite and conglomerate masses strew the sides and bases of the hills.

The Gokák scarp disappears northward under the Deccan trap at Arbhavi, four miles north of Gokák. To the south it forms two bold headlands jutting east. Further south it is lost, and the beds forming it dip southward, and then roll generally at low angles over a large area covered with small wooded hills on the banks of the Kelvi and its tributaries. It stretches south through Lakhmápur and Deshnur to Marihal, about ten miles east of Belgaum, east to Mamdápur and Nandi, and west to the Márkándeya river on the Páchápur-Ankalgi valley. Throughout this region the sandstones less frequently assume the character of quartzites, having been exposed to a decidedly smaller degree of metamorphism. The coarser beds, as conglomerates and grits, show little change, but

[1] The head of the fissure is elliptical in form, with mural sides of sandstone, which, in its lower portions, is interstratified with layers of shale of a purplish-brown and yellowish-brown colour, with minute spangles of mica disseminated and between the laminæ containing incrustations of common alum. The head appears to have been cut back about 100 yards by the wearing of the water. Large rocks with angular unworn surfaces evidently dislodged from the rocks on the spot are seen in the bed and on the sides of the river below the deep receptacle of the fallen waters and on its margin. At the bottom of the deep fissures in the sandstone cliffs there were heaps of fallen fragments of rocks intermingled with bones and dung of bats, rats, wild pigeons, sheep, and goats. The upper portions of the fissures, with their sides marked with shallow polished grooves, were also choked with rubbish and rocks. Captain Newbold made two holes through the floor of the chief fissure. After penetrating the surface layer of loose stones a fine red earth was found imbedding angular fragments of sandstone and a few rounded pebbles of sandstone and quartz. Geological Papers on Western India, 355, 356.

some of the fine grained beds, even where they lie horizontally or very nearly horizontally, are true quartzites. Where the beds have been disturbed the amount of metamorphism is in direct proportion to the amount of disturbance.

The same characteristics are found in the rocks that stretch west across the Márkándeya river to the Kákti and Kankumbi scarps near Belgaum and along the upper valley of the Ghatprabha past Konúr, Ghodgiri, Majti, Vatmuri, Sutgatti, and Daddi to the extreme west of the Kaládgi basin at Vatangi. The two gneiss inliers of Iranhatti and Yellápur seem to be high points of the old gneissic surface, round which the true basement beds of the quartzite series are not exposed.

The lower Kaládgi quartzites and sandstones at Vatangi in the extreme west are covered on three sides by Deccan trap flows. Beyond the ridge of trap, which covers the quartzites west and north of Vatangi, the quartzites reappear in the valley of the Harankáshi, occupying a considerable area near the village of Mángaon. The rocks that form this inlier present no peculiar features. They are quartzites and grits which mostly dip northward or north-west at low angles. They are best exposed in the row of hills which runs south-east from Salgaon on the bank of the Harankáshi and joins the trap ridge. The quartzites and grits are mostly pale coloured and fine-grained, and form a series of beds several hundred feet thick. Of the same character of rock are the beds that form smaller inliers in the valley of the Vedganga, eight miles north-west of Mángaon. These lie in the centre of the valley between Yengol and Shengaon and are four in number, the southmost, close to the village of Yengol, forming a small outstanding hill 200 to 300 feet high. Here all the beds dip north-west 5° to 10°. The other inliers are simply exposures on the flanks of the great ridges.

Passing to the south-west limit of the quartzite series, at Kákti, about five miles north of Belgaum, the rock forms a scarp whose base is hidden by a thick talus, or slope of fragments, abutting on a broad alluvial flat, which has gathered in the valley of the Márkándeya above the gorge by which that river flows through the congeries of hills and small quartzite plateaus that lie between Kákti and the Ankalgi valley. This scarp is merely the north-west continuation of the scarp that forms the boundary of the quartzite plateau to the north of the Belgaum valley, and along the entire base of which the underlying metamorphic rocks are to be seen. From the relative position of the trap flows that form the base of the great flat-topped One Tree Hill to the north-east of Belgaum, it is clear that the Kákti scarp was formed before the outpouring of those particular trap flows, and not improbably before the very earliest trap flows. It is not unlikely that this scarp extends far to the north-west under the overlying trap. The form of the ground at Rájgoli on the Támraparni, and at Yengol in the valley of the Vedganga, suggests the idea that the scarps there seen are really the great boundary scarp of the westward extension of the Kaládgi basin, although the base of the scarp is not sufficiently uncovered to show the underlying metamorphics.

Chapter I. Description. Geology. *Lower Kaládgi Quartzites.*

Both above Kákti and along the south scarp above Kankumbi a succession of conglomerate and grit beds, with some compact quartzites intercalated between them, are seen to dip north or north-east at low angles. Farther north other gritty and pebbly beds are met overlying the beds which form the scarp. These scarp beds pass across the slightly inclined plateau to the gorge of the Márkándeya near Nandi, north of which come other quartzites which stretch to the valley of the Ghatprabha near Sutgatti and Vantmuri about half-way between Daddi and Páchápur. The very gritty and conglomerate character of the beds in the Kákti plateau changes gradually eastward, so that near Hoskatti and Hanbarkatti quartzite beds predominate. How very greatly this part of the Kaládgi basin was worn before the trap was poured out is shown by the quartzite beds that cap the Budnur hill, a gneissic inlier among the trap. A fine section of the quartzites, which there form the basement of the Kaládgi Series, occurs in the valley north of Siddápur, where the Budnur stream enters the Kaládgi basin by a picturesque gorge. The beds dip 12° north-east. At the next gorge eastward from Siddápur the edge of the basin is more than usually uptilted and the quartzite beds have a dip of 30° to 35° north-east.

At Murgod, in the west of Parasgad, a set of quartzite beds forms the actual base of the series, and is overlaid by a set of conglomerates with sandstone forming the surface of great part of the plateau east of the village. The surface of this plateau has been greatly broken by weathering, but has reformed into a breccia pavement made of an iron cement apparently of sub-aërial origin. The pebbles included in the conglomerates are mostly of an older quartzite, probably of gneissic age. The beds which form the plateau east of the village rise eastward to the apex of the flat dome of Kathárigad. The arch of the dome is seamed by deep fissures, which, cutting through the mass of quartzites, show the underlying granite gneiss. East of Kathárigad the quartzites sink rapidly into the valley of the Benákatti, a tributary of the Malprabha. To the south of Kathárigad, the rocks at the Sogal waterfalls are hard quartzite conglomerate, pale, reddish-brown, or purplish, and numerous bright red jasper pebbles form the hæmatitic beds of the Malprabha valley. The southern boundary of the Kathárigad erosion valley is formed by a considerable fault which runs west 29° north, and has caused an upthrow of the beds on its southern side. The fault stretches along the south of the ravine north-west of Karlhatti.

The rocks that form the beautiful gorge of the Peacock's Pool, or Navil Tirth, nine miles east-south-east of Sogal, are hard quartzites extremely polished within water reach. The polished surface is in most places covered with a thin film of dark grayish-black, a striking contrast to the delicate pale-red and pink of the other quartzite rocks. In the gorge, bed after bed may be traced upward or downward without a sign of doubling. The dip varies from 10° to 15° and averages about 12°. The leading colours are pale light red and pink and drab, with a few beds of light bluish-gray. Near the base some of the quartzite beds are of bright red salmon colour, or even of a pale peach blossom. Many minor beds among the quartzites are very pebbly,

Lower Kaládgi. Quartzites.

in fact are perfect conglomerates. Among the included pebbles and fragments are many of red and gray jasper from the hæmatite beds in the gneiss. Pebbles of quartz and other quartzites, also of hornblendic schist and of pistacite, are common among the inclusions. The quartzite beds often contain isolated pebbles, which, especially when of red jasper, contrast strongly with the generally uniform texture of the matrix. Taking the length of the section at one and a quarter miles directly across the ridge the total thickness of quartzite and conglomerates cannot be estimated at less than 1200 to 1300 feet; the average dip of 12° being perfectly steady throughout the greatest part of the section. Most of the faces of the cliffs exposed in the Peacock's Gorge correspond with some of the principal lines of jointing by which the whole quartzite series is permeated.

To the north the quartzites dip under a thick series of clay schists which stretch across the flat immediately north of the gorge to a low quartzite ridge, formed by a reappearance of the upper basement series in a sharply flexed anticlinal which abuts on the left bank of the river close to Manoli. Beyond Manoli the quartzite again disappears under schists. To the west this anticlinal sinks very low, and then rises and joins the south-east extension of the Kathárigad plateau south of Madlur. The large village of Manoli stands on the clay schists and is chiefly built of a flaggy variety exposed during the dry season in the bed of the Malprabha immediately opposite the village east of the Peacock's Pool. The Kaládgi basin is bounded by a line of bluff quartzite hills, showing here and there precipitous scarps, whose bases are everywhere hidden by fragments of rock. The underlying gneiss is seldom seen. The chief outlier of the quartzite beds to the south is the Parasgad hill, about eight miles south of Manoli. The quartzites of this hill along their northern boundary are faulted against the gneiss and form a great inclined plain with an average dip of 7° north. In many parts the surface shows vast sheets of bare rock. In a cave about 200 feet below the edge of the scarp is a very interesting spring, whose water must drain through joints in the rock from the brow of the hill.

Lower Kaládgi Limestone.

The clay schists that overlie the basement quartzites at Manoli stretch from some distance north-west of Yargatti, south-east to the Malprabha at Manoli, and across the Malprabha into the spurs of the hills that run north-east parallel with the river, and pass into quartzite or sandstones among the hills south-west of Rámdurg. To the north of the clay schists comes in sometimes a 'dirty' hornstone breccia, sometimes a set of highly silicious (cherty) limestones, whose extension is in great measure masked by the great accumulations of cherty debris derived from the weathering of the cherty beds, together with great spreads of cotton soil and also of sand formed by the decay of the silicious beds on the higher grounds. These silicious limestones appear to be distinct from the great limestone formation that occupies the Ghatprabha valley near Kaládgi. They stretch from Ujenkop south-east to Jakkabal on the Malprabha north-east of Manoli, and are connected with a patch of similar character that occurs at Gorāganur further down the river. To the west of Yargatti, on the Belgaum-Kaládgi road about

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Lower Kaládgi Limestone.

ten miles north of Manoli, the limestone beds roll in low reefs forming a rocky wilderness six to eight miles square. Over this area to the west of Yargatti the 'dirty' breccia is not seen. To the north-east of Yargatti are some beds of pink and pinkish gray limestone of less silicious character. In the hilly ground to the south-west and north of Torgal a thick series of sandstones with a few conglomerate and quartzite beds overlies the silicious limestones and dirty breccia, and forms a low rolling plateau very stony and barren. To the north, between Torgal and Karikol, the land is mostly a rocky wilderness of sandy soil, deep cut by streams and covered with scrubby brushwood. Further north the sandstones are represented by the drab shaley series and the overlying quartzites. The only remaining section of the quartzite basement series is a narrow strip to the north of the long spur of Deccan trap that forms the watershed between the Malprabha and the Ghatprabha. The most westerly part of this strip forms a high rocky ridge culminating in the Manikeri hill about twenty miles east of Gokák. Its red and drab quartzite beds have a north-east dip of 30° to 40°. At Hulkund the ridge is crossed by a stream, but rises again to the east and forms two conspicuous rocky hills, the southmost of which dies down in an anticlinal ellipse. To the west the anticlinal character of the ridge is obscured by the trap which surrounds the hill to a great height. Rather more than half a mile east of the elliptical end of the anticlinal other sandstone and quartzite beds are exposed. These probably belong to a rather higher horizon in the series.

The lower Kaládgi limestones and associated shales are found chiefly on the north-east part of the Kaládgi basin. A considerable extent of them occurs between Lokápur north-west to the Ghatprabha. These rocks lie partly within Belgaum limits to the east south and west of Yádvád, and partly in the Mudhol and Jamkhandi villages in the east of Belgaum. These limestones occupy a basin within the Kaládgi basin, and with boundaries in many parts fairly parallel to those of the great basin. The western boundary is formed almost entirely of the overlying traps, and there are a small number of limestone inliers beyond the north-west corner of the limestone basin. The limestone basin includes within its area a number of minor basins and outliers of rocks, quartzites, limestones, and shales that lie conformably on it and form the upper division of the Kaládgi series. From their low position, and from the great amount of contortion to which they have been subjected, it is difficult to fix the precise relations of this section of the Kaládgi Series.

At and round Yádvád is one of the largest shows of limestone in the whole region. The prevalent beds, mostly seen in the bed and banks of the Yádvád stream, are gray in various shades, but other colours as white-banded gray and white, greenish gray with pink, and white bands and grayish green are also found. The great plain south of Yádvád is covered by an almost unbroken sheet of typical cotton soil or regur through which rocks show only in a few widely scattered places. A little to the north-east of Monami banded green and white limestone, with some white and pink bands, occurs in

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Lower Kaládgi Limestone.

small sections. The broken outliers from them in a limestone basin west of Yádvád stretch about twelve miles north-west to Beshati near the Ghatprabha. Large shows occur between Hal Yergudri and Uradi, six to eight miles north-west of Yádvád; between Bisankot and Beshati from ten to twelve miles north-west; at Kulgur about ten miles west; and between Has Yergudri and Temápur, between four and six miles west. In the long valley that stretches south from Temápur the limestones are red, pink, and banded with gray, green, and brown. The beds are mostly much crumpled and the true dip is often doubtful. At Alimati, about eight miles north-west of Yádvád, are handsome brecciated beds of drab limestone cemented by a purple matrix. At Manápur, about one and a half miles south of Alimati, beds of dull red earthy limestones are associated with red chert, lumps of which are scattered on the surface.

The limestone on the two outliers south of the limestone basin near Sidanhal, eight miles north-west of Torgal, shows flaggy purple beds, sometimes rather earthy. They roll a good deal at low angles, and to the south are underlaid by beds of cream-coloured and whitish limestone which occur in the Tolagati stream a little to the south of Sidanhal. Returning to the main limestone basin by the Belgaum-Kaládgi road, gray and whitish limestones, some of them very cherty, are crossed on the north-east of the Panchgaon travellers' bungalow about eight miles north-east of Sidanhal. To the north-west of these is a large show of earthy sub-crystalline beds of red and pink which dip under the Lokápur synclinal. Further east, at Varatsgal in Mudhol, about two miles south of Lokápur, are numerous beds of gray limestone. To the east and west of Lokápur gray and bluish-banded limestones are largely exposed, and make the largest show in the whole limestone basin. The Belgaum limestones are almost entirely free from quartz reefs and veins. A few veins are found to the south-east and north-west of Hoskati, about a mile to the west of Lokápur.

Upper Kaládgi Series.

Rocks of the Upper Kaládgi Series, quartzites below and limestones and shales above, are found in bands resting conformably on the lower series, and occupying a number of small basins which form elliptical synclinal valleys. They lie on the whole east and west. The series nowhere passes beyond the limestone basin, and the area it occupies is extremely small. The chief are to the west of Lokápur, to the north-east of Yádvád, and some smaller outcrops on the Deccan trap area, near Alimati, about eight miles to the north-west of Yádvád. The quartzites of this upper series are very uniform, pale, and frequently conglomeratic, with local patches of brecciation. It is worthy of note that all the ridges of this series are cut by streams on their way to the Ghatprabha through weak spots caused by excessive jointing. A section in the gorge through which the Lokápur stream enters the basin from the south shows in descending order

3. Breccia of Quartzite.
2. Calcareous Shales with Limestones.
1. Quartzites with Pebbly Beds.
Fragments hiding Calcareous Shales.

The calcareous series that rests on the upper quartzites consists

Chapter I. Description. Geology. *Upper Kaládgi Series.*

almost entirely of calcareous shales purplish or gray and overlaid by purple and gray argillaceous shales; limestones show only occasionally and generally in thin bands. In some parts the purple shales are highly ferruginous, being richly charged with earthy red hæmatite. As a rule the surface of this series is thick covered by cotton soil or by thick, red, ferruginous, gravelly soil formed by the decay of the hæmatitic shales. Limestones of this series occur at Murgar in Mudhol about four miles east of Yádvád, at Jembigi about four miles further east, at Yenkatpur a little to the north of Lokápur and at Varatsgal about two miles to the south of Lokápur.

Intrusive Rocks.

The only Intrusive Rocks in the Kaládgi basin are trap dykes, which are sparingly distributed and occur only in the upper part of the series. There are three trap dykes near Lokápur, all of compact green diorite weathering in concentric ellipsoidal masses unlike any of the older diorites seen in the gneissic area. Their course is north-west by west to south-east by east, and they show only in the centre of the valleys among the shales. In the absence of organic remains and from its isolated position it is impossible to correlate the Kaládgi series closely with other series rich in quartzites. Still, the character of its rocks is much like the character of the rocks of the Kadapa Series and of the Gwalior or Bijávar Series of Central India.

Infra-Trappean Rocks.

Underlying the great Deccan trap, and resting sometimes on the gneissic and sometimes on the Kaládgi series, are certain deposits of sedimentary origin of small thickness and extent. They are interesting, as some of them may represent the pre-trappean deposits of Central India which are known as Lameta beds from the Lameta pass near Jabalpur. Unlike the hard rocks of the Kaládgi Series these deposits are in a soft unconsolidated or half-consolidated state. They are formed of the ruins of various older rocks with a considerable mixture of the red earthy clay called bole in isolated lumps, or in strings, or generally spread through the mass. The most common form of these deposits is gritty marly clay or clayey grit, as at Malanhatti three miles north-east of Gokák, and at Kulgur twelve miles north-east of Malanhatti. Coarse shingle, mainly gneiss and quartz pebbles, seen largely at Nágarhál east of Yellurgad near Belgaum, is the remains of former pre-trappean deposits. The most extensive exposure of these infra-trappean beds is near Sigihalli, about ten miles south-east of Belgaum. The sandstones here are seen in very thin courses in soft sandy marl resting on hornblendic schistose gneiss. These infra-trappean beds are eight to ten feet thick. As far as is known they contain no fossils. The presence of bole in so many of the pre-trappean deposits appears to be due to the heating action of the trap flows poured on to beds of fine clay. The quantity of the bole is always largest close to the trap, where it occasionally occurs pure and much broken by minute cracks. The pure bole is rarely many inches thick. In some cases it is very markedly affected by a system of prismatic jointing on a small scale; but the mass is so friable that it is impossible to collect any of the very pretty little prisms; they crumble even with the most delicate handling. From the circumstances under which they occur, from

their limited extent, and from their strong resemblance to the fresh water deposits among the lower trap flows the infra-trappean beds may be set down as of limestone origin.

The north half of the district and two great spurs, one that runs from near Gokák south-east to near Rámdurg and the other that runs from Belgaum about twenty-five miles north-east, that is about three-fourths of the district, are trap. The depth of trap grows gradually greater from the east to the west. In the east where only a few flows have spread are low rolling downs with shallow valleys between; further west later flows rise in flat-topped ridges between the water-sheds of the larger rivers; and still further west the latest flows are piled into high and massive hills.

The chief varieties of trap are basalt, amygdaloid trap, vesicular trap, and clayey trap. These, with some few intertrappean sedimentary beds and numerous highly iron-charged clayey beds make up the mass of the trap flows. By far the commonest rock is basalt. This includes, besides compact and vesicular basalt, the highly weathered earthy trap so common throughout the Deccan. In form basalt is either massively shapeless, rudely tabular, or rudely columnar, the two last forms being the most common. The lower flows are mostly basaltic, the middle flows alternately basaltic and amygdaloid, and the upper chiefly basaltic, capped by beds of laterite and clay. The lower trap flows were poured over an exceedingly rough surface. The upper flows often overlap the lower and rest on the higher parts of the older rocks. In the west, when studied from some commanding point, the flows are seen to dip at a low angle to the north-east. About twenty-five or thirty miles from the Sahyádris the dip becomes more easterly, and so gradual as to be hardly perceptible. The absence of centres of eruption and the rarity of beds of volcanic ash seem to show that the volcanic centres through which the trap was poured were north of the Belgaum district. That the trap flows were poured out in the air and not under water is now generally accepted as proved. Of the age of the trap nothing has yet been determined. The intertrappean beds occur near the local base of the traps. These beds are of small extent, and are found only along or near to the south-east edge of the trap area.

The grandest sections of trap are to be seen in the great western scarp of the Sahyádri hills. Their great thickness, some of them forming cliffs several hundred feet high, makes the flows very difficult to study. But they can be well examined in the cuttings on the roads over the Phonda and Ámboli passes. To the east the best sections are the bare hills round Chikodi, Bágedgudd north of Gokák, and Yellúrgād south of Belgaum.

The series of trap flows seen in the bare hills round Chikodi consists of six basaltic flows. The three lowest are separated from each other by thin beds of amygdaloid trap and red bole. The highest flow is separated from the rest by thin boliferous beds, part of which may be volcanic ashes. The two middle flows, though distinct, show no intercalated matter. The whole makes up a thickness of 600 to 700 feet, of which the three lower basaltic flows occupy fully two-thirds.

Chapter I. Description. Geology. *Deccan Trap.*

The bare slopes of Bágedgudd, about two miles north of Gokák, give a very good section. This is the most easterly point at which the uppermost trap flows occur. From the south eight chief flows may be seen over the water-shed ridge that divides the valleys of the Ghatprabha and the Krishna. They are best seen from a distance, as close at hand the ruggedness of the slopes masks the terrace structure. Beginning from the highest the succession is (1) iron clay (laterite); (2) amygdaloid; (3) basalt; (4) basalt; (5) amygdaloid, red and brown; (6) basalt; (7) amygdaloid, purplish and soft; and (8) basalt. The lower beds stretch far on all sides, and may be traced for many miles in the spurs that branch from the great central mass. Its lower flows connect Bágedgudd with the Chikodi hills about twenty-five miles to the north-west, with the Manoli hills about the same distance to the south-east, and with the lower basaltic plateau that stretches along the north frontier of Mudhol about the same distance to the north-east. To the north of Gokák the lower Bágedgudd flows form several rocky ridges which stretch into the Krishna valley. The hills near Athni and Gateh may be said to be extensions of the Bágedgudd series. The dolerite and basalt flows that form the group of hills at Gosbal and Kauljalgi about fifteen miles east of Gokák represent the three lower members of the Bágedgudd sections.

The iron-clay bed which caps Bágedgudd is the youngest known, the most constant, and the most safely determinable member of the local Deccan trap series. As it caps all the highest ridges and peaks in Kolhápur and Belgaum it may be called the summit bed. Of all the mountains those which it caps are the most perfectly table-topped, and in most cases the capping is sharply scarped all round the edge. As these scarped plateaus crown all the highest hills and were easily made very strong, many of them were chosen by native chiefs as sites for their strongholds. Such are Gandharvgad about twenty and Mahipálgad about twelve miles north-west of Belgaum, Kálánandigad about sixteen miles west of Belgaum, and Yellurgad about eight miles south of Belgaum. Further north the same rock forms the hill-forts of Samángad and Bhudargad, about twenty-five and forty miles north of Belgaum in South Kolhápur, and of Vallabhgad and Páijargudd in Chikodi. Underlying the great iron-clay bed is a bed of clayey trap often purple and much softer than the overlying bed. The more rapid weathering of this clayey trap bed is the reason why the scarp so constantly and sharply defines the iron-clay summit bed. This clayey trap generally passes into ordinary purple or reddish brown amygdaloid, below which are basaltic and other amygdaloid flows. The clayey trap is largely developed on Kálánandigad about sixteen miles west of Belgaum, and on Bailur fourteen miles south-west of Belgaum, the highest hill in the district 3491 feet above the sea. Further north the clayey trap is well seen on Vallabhgad and Páijargudd in Chikodi.

A somewhat striking feature of one of the basaltic flows, which, at many parts of the southern boundary, forms the basement bed is the weathering into great rude blocks, some of which might almost be reckoned small tors. These blocks frequently rest directly on the underlying gneiss. At Bastvád about eight miles south-west of

Belgaum, at Nágarhál about two miles east of Yellurgad, and to the north-west of Murgod in Parasgad, a few big blocks remain isolated on the gneiss at small distances from the boundary of the basalt flow. At Bavihal two miles north of Sampgaon, an unusual variety of trap occurs below the blocky basalt flow which generally forms the base in that quarter. This exceptional variety differs from any other Deccan trap in being much more crystalline in texture and resembling far more a highly hornblendic diorite of gneissic age. The upper part of the intermediate bed consists of pure bright-red bole, two to three inches thick, which shows very distinct prismatic columnar cleavage.

Typical basalt which occurs in innumerable places, is largely quarried on the slopes of One Tree Hill north of Belgaum. It is a fine close-grained brownish black stone with a few small vesicular cavities. A variety which is porphyritic from enclosing rather large crystals of green glassy-looking olivine, was observed on the high hill which forms the north-eastern extremity of the Yellurgad ridge.

Volcanic ash-beds are not numerous. They are found in the flanks of Vallabhgad about fourteen miles south-west of Chikodi, and in the north Ghatprabha range between Chikodi and Valur in south Kolhápur. The beds may at first sight be easily taken to be amygdaloid flows, but examination shows that they are chiefly of fragments, lapilli, or volcanic ashes and dusty particles of vesicular trap cemented by the deposition of calcite and zeolitic matter in strings and films between the fragments as well as in the vesicular cavities. The lapilli are mostly reddish or purplish, and much red bole is spread through the mass, which, by contrast with the whitish calcite and zeolite, makes the whole reddish or pinkish gray.

Columnar cleavage of basalt is occasionally seen in the west, but is generally rude and unworthy of note. The best case is probably the cutting at the top of the Phonda pass. In the Konkan, west of the Rám pass, Mr. Wilkinson noted fallen masses of perfectly-columnar trap.

The mineral substances enclosed in the trap flows are not very numerous. Zeolites, chiefly scolecite and stilbite are very abundant in small or large vesicular cavities in many trap flows. An uncommon crystalline form of heulandite was found in a purple amygdaloid at Dandápur, nine and a half miles north of Gokák. The crystals occurred lining irregular clefts in the rocks.

Small agates are found in large numbers on the weathered surfaces on the ridge north of Chinchni three miles west of Chikodi, at Kurgaon eight miles south east of Chikodi, and near Hamámságar twenty-miles south-east of Gokák.

Some curious fungoid concretions of chalcedony and rock crystal are found in a soft clayey amygdaloid flow south-east of Dehmangi, about four miles south-east of the Belgaum fort. Similar concretions also occur on Kálánandigad sixteen miles west of Belgaum. Calcspar occurs frequently both in basaltic and in amygdaloid traps. Magnetic iron is spread in considerable quantities through the mass of the basaltic and doleritic trap. Arragonite occasionally occurs in doleritic

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trap flows. Red bole frequently occurs in amygdaloid beds and in some volcanic ash-beds as in the slopes of Vallabhgad in Chikodi. Olivine is not very often seen. The best specimens occur in the first high basaltic hill south-west of Nesargi on the Belgaum-Kaládgi road.

Inter-trappean Beds.

Between the flows of lava that make up the Deccan trap, sedimentary rocks, chiefly sandy deposits, conglomerates, grits, and clay beds sometimes occur. In a few of these fossils have been found, whose organic contents show them to be of fresh water origin. The similarity of their mineral character leaves little doubt that all these rocks were formed in fresh water lakes. Though their mineral character differs, the fossils, Physa prinsepii, Lymnea, and Unio deccanensis, prove that the traps of the Southern Marátha Country and of Central India belong to the same period.

The Southern Marátha intertrappean beds lie near the base of the trap series. In one important case a fresh water marl was found resting on the gneiss rocks, and thus underlying what locally appears to be the lowest trap-flow. This may have been caused either by the flow overlapping some older flow or by its representing the deposits in a fresh water lake older than the first outpouring of the Deccan traps. In two intertrappean beds within Belgaum limits, at Mamdápur, six and a half miles north-east of Gokák, and at Uparhati, a mile north of Mamdápur, organic remains have been found.

The intertrappean beds near Mamdápur in Gokák seem to have been formed on the shore of a lake. They have a considerable show of bright red sandy marl, the red being due to the somewhat abundant presence of bole. Under the red sandy marl with lime nodules and many gneiss and quartzite pebbles is a bed of pale-drab sandstone with lumps of quartzite and Unio shells. This sandstone rests on red marl, and the red marl on a greenish-yellow marly-looking bed of decomposed vesicular trap that passes into dark greenish-black vesicular trap, with many small and a few large agate amygdaloids. The whole thickness of marls and sandstones ranges from fifteen to twenty feet.

A little more than a mile from the Mamdápur section, separated from it by an exposure of gneissic rock, rises a low flat-topped ridge, on the west side of which, close to the village of Uparhatti, the intertrappean rocks again show. The exposed beds are quartzite and gneiss shingle of uncertain age; weathered basaltic trap; red sandy marl with three or four sandstone partings containing *Unio*[1] shells and decomposing whitish amygdaloid trap.[2]

Patches of shingle, chiefly of quartzite, appear from their position to be the relics of some intertrappean formation that has been worn

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[1] The *Unio* beds are about twenty feet thick, and were formerly continuous with those of Mamdápur. The fossil *Unios* in both sections are well preserved, even the beautiful lining or nacre being kept in some instances.

[2] This section represents the beds north of the village in order to introduce the quartzite and gneiss shingle. The *Unios* were found a few dozen yards south of the village.

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away or masked by surface fragments. Of the latter class are the patches of quartzite gravel at Kolik and Chiguli, on the south side of the Tilári ravine, eighteen miles south-west of Belgaum. A similar gravel patch occurs at Volmani, a mile east of Jámboti, about fifteen miles south-west of Belgaum, and at much the same level relative to the trap-flows. Near the western end of the great trap spur north-west of Párgad, about four miles west of the Rám pass, there is another gravel patch in which quartz pebbles predominate. To the class of gravels that represent worn intertrappean beds most likely belongs a large spread of quartzite shingle that lies on the surface of the trap on rather high ground three or four miles north of Yádvád. The curious bed of quartzite shingle that caps the Uparhati hill near Mamdápur may also belong to this class of relics.

The position of some of the lateritoid or iron-clay rocks intercalated between trap-flows in the high western ridges suggests that they may be of intertrappean sedimentary origin. This is the case with some iron-clay beds on the south side of the Jámboti ridge seen on the path leading from Chikhli to Ámti. Other iron-clay deposits occur here and there over the trap area, which, though very likely the results of sub-aërial atmospheric action might, from their position, be regarded as intertrappean relics similar to the quartzite gravels.

The only instances of intertrappean limestone are two small exposures of flaggy light-brown oolitic limestones that occupy depressions in the surface of the trap and are obscured by the surrounding cotton soil. One of these is in the hollow at the foot of a hill south-west of Nesargi on the Belgaum-Kaládgi high road. The other is at Ghone, a village six miles east of Nesargi. Neither bed seems to have any signs of organic remains.

Iron-Clay.

The traps in many parts of the district are overlaid by an iron-clay rock. This rock is of two kinds somewhat hard to distinguish, and both of them formed of decomposed trap. The first are much changed from their original state by weathering; the second are collections of ruins of rocks of the first class. The rocks of this second class are probably partly made of altered sedimentary rocks, but they are chiefly altered lava flows. It is convenient to call the altered lava flows iron-clay rocks, and the altered sedimentary rocks laterite, the name originally given to the fringe of ferruginous deposits that surrounds the southern part of the Indian peninsula, and almost certainly appears in the South Konkan or Ratnágiri laterite. When the Southern Marátha iron-clay was formed the country had probably acquired nearly its present features. The weathering of trappean rocks into iron-clay rocks is well seen in the cutting on the Phonda and Ámboli pass roads. The basaltic rocks graduate into a moderately hard brown earthy mass, which encloses many nuclei of the original rock. The infiltration of surface water charged with iron has solidified the decomposed mass. The summit bed, which has already been noticed as capping many of the highest hills, seems to have been formed of a trap rock entirely without silicious segregations.

The underlying trap into which the summit bed is seen to graduate at the principal sections, as Vallabhgad and others, is a very clay-like rock without any enclosed minerals. In colour and fineness of

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texture it resembles many of the purple, brown, reddish amygdaloid beds that occur so largely elsewhere, but differ in the total absence of vesicular cavities whether empty or full. Besides the highest ridges and peaks in the Belgaum section of the Sahyádris, which have their summits capped with iron-clay, there are many others on which an iron-clay capping forms a very marked feature. Some of the most important of these cappings form outliers[1] on the older rocks where the latter are of great elevation and stand above the general mass of the trap flows, but are overlapped by the ferruginous beds. Owing to the superior hardness of the highly ferruginous summit bed, and the more rapid weathering of the underlying beds, the surface of the underlying beds is generally covered by ruins or by great fallen masses of the upper beds. In other sections a quasi-stalactitic ferruginous rain-wash often affects the appearance of the surface of inaccessible cliffs. And the presence of numerous delicate gray, orange, pale-pink, and flesh-coloured lichens in many cases so greatly changes the colour of the scarp faces that they can be made out only on close inspection.

Within Belgaum limits the three best sections of the Deccan trap iron-clay are at Kálánandigad sixteen miles west of Belgaum, and at Vallabhgad and Páijargudd in Chikodi. The iron-clay rocks of Kálánandigad are best seen on the path up to the north gate of the fort. The hundred feet at the top of the hill consist of mottled purplish and white or purplish clayey rock, which, without any sudden change, passes into a compact lateritoid mass.[2] The hill-sides become scarped as soon as the level of the summit bed is reached.

At Vallabhgad the clayey under-rock shows a good deal of quasi-vesicular structure in the arrangement of colours. Numerous thin films of white are seen like other vesicles enclosing darker portions of the general mass. The ruling colours are purple and reddish-brown, much flecked with white vesicle sections. The iron-clay summit bed, instead of showing horizontal or approximately horizontal vesicular cavities in the mass, is permeated by vertical tubuli running nearly through it. The upper beds of these tubuli, which vary in

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[1] The chief outliers of the summit bed, counting from the southern extremity of the trap area northward, are: (1) The Jámboti ridge; (2) Bailur with a peak 3491 feet high; (3) the Kárle and Báknur hills south-west of Belgaum; (4) Kálánandigad and Mátungi and the high spur connecting them with (5) the Mahipálgad ridge; (6) the Gandharvgad ridge; (7) the Vágbud and Kásarsudda plateau west and south-west of Chándgad; (8) the high ridge between the Ghatprabha and Harankáshi south of Amboli, and also from a little north of the Belgaum and Vengurla road north-east to the Khánápur Trigonometrical Station hill near Ajra; (9) the high ridge dividing the valleys of the Ved and Dudhganga rivers, including the well marked plateau north of Pyáh; (10) the Vallabhgad outlier; (11) the two Bágedgudd outliers, on the eastern of which is a Trigonometrical Station; (12) the group of outliers west and south-west of Gokák, two of which overlap the Kaládgi quartzites; (13) the Páijargudd group of four small outliers, with a fifth forming the summit of Huligarkit hill three miles to the east; (14) the Arlehatti outlier four miles west of Páchápur resting directly on the quartzites; and (15) the Yellúrgad outlier eight miles south of Belgaum, the last of the summit bed outliers. Several other outlying patches of similar iron-charged clayey rocks occur in the more eastern parts of the trap area, but they are too distant to be safely correlated with the summit bed.

[2] Captain Newbold supposed that the beautiful lilac colour of the lithomargic earth underlying the iron-clay of the Bidar plateaus was due to the presence of manganese. This supposition is probably correct. Memoir Geological Survey of India, XII. 206.

diameter from a quarter to three-quarters of an inch, but which are generally less than half an inch across, are empty for a little distance, giving the surface a pitted appearance. But the tubes are generally filled with lithomargic clay and have their walls lined with a glaze very like the glaze which occurs in the vermicular cavities of ordinary laterites. The height of the tubuli which are less distinct in the lower parts of the bed, and whose formation is due to the action of percolating water depends upon the thickness of the bed, and the glazed sides show much stalactitoid waviness of surface.

Iron-Clay.

The section seen in Páijargudd hill shows a thick-bedded mass of iron-clay with little or no tubulation, resting on a clayey trap of generally gray or purplish colour, finely streaked and mottled with reddish-brown, orange, or dull yellow. The vesicular markings noticed at Vallabhgad are also seen here, but are less common.

Pisolotic Iron-Clay.

A very peculiar pisolitic form of the iron-clay, varying in colour from pale brownish pink to bright or deep red or purple, is observed in several places, chiefly on Yellurgad, on Bailur, and on the Kásarsudda ridge south-west of Chándgad. Where this pisolitic iron-clay occurs the rock has a decidedly jaspideous texture and look, its colour varying from pale brownish pink to bright or deep red or purple according to the percentage of peroxide of iron.

A very extensive show of lateritoid iron-clays occurs at and to the east and west of the Rám pass. The rock there forms a nearly level ridge with a ragged scarped edge and a slope of great fallen masses. This ridge stretches north-east into the higher spur west of Hire, while, to the west, it joins the Isápur plateau north of Párgad, along the north side of which it forms a very distinct and generally vertical scarp thirty to sixty feet high. The Rám pass bed rests in some places direct on a basaltic flow without the intervention of the thick clayey trap. It is probably distinct from the summit bed, as it is considerably lower and does not lie in a level plane.

At apparently the same level are several ragged-edged plateaus south and west of the high Kásarsudda ridge about the head waters of the Ghatprabha. To the same set belong the beds on the high ground south-west of Patna and at Kodali on the north side of the Tilári ravine.

Sedimentary Iron-Clay.

South of the Tilári ravine at Kolik, Chigoli, Kankumbi, Huland, and stretching west towards Chorle and to the extreme western points of the Sudda fort spur, overlooking Goa, are continuous sheets of the iron-clay belonging to a bed or beds occurring very much at the same level. Southward, past the top of the Párvár pass, these sheets join those at the foot of the Jámboti ridge and pass south-east, forming, near Ambgaon and Chapoli, a well-defined plateau which caps the extreme southern promontory of the great Deccan trap area overlooking the Mahádáyi ravine. From the edge of this ravine the iron-clay beds seem to be represented on its southern side by a similar set which form a plateau round Gausi. To the north of the Rám pass, this set, which for convenience may be called the water-shed series, is represented in the plateau near the source of the Ghatprabha and in the valley of the Harankáshi.

The bed of iron-clay which forms a well defined plateau on the

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high spur south of Chapoli is of sedimentary origin. The sides which are well scarped show a vertical thickness of fifteen to twenty feet of the tubulated variety of iron-clay, the tubulation being very strongly and clearly developed.

From the number of quartz pebbles imbedded in the clayey mass it may be inferred that this iron-clay represents wholly or in part an altered intertrappean pebbly clay of the kind found in various typical intertrappean beds.

Along the south side of the Jámboti ridge, on the path leading from Chikhli to Ámti, are several alternations of iron-clay and basalt at different levels, the iron-clay apparently forming distinct terraces corresponding to altered trap-flows or intertrappean beds.

Three sets of small iron-clay plateaus, occupying rather lower levels than those of the water-shed series, occur in the valleys of the Márkándeya, Támraparni, and Ghatprabha. Those of the first and last sets form small groups of barren flat-topped hills, those on the Márkándeya near Unchgaon on the Belgaum-Vengurla road, and those on the Támraparni to the south of Arkur. Besides these there are similar minor and less marked plateaus in the upper parts of the valleys of these rivers.

The iron-clay at Belgaum occupies a deep bay or hollow on the east side of the basaltic rise on which the new European barracks have been built. The basaltic high ground here forms an angle, the apex of which lies north-west of the town, and, in that angle, the iron-clay is most largely exposed in two sections, one in the well in the soldiers' garden, the other in a deep well-like pit. In the soldiers' well the iron-clay had not been pierced at a depth of thirty-five to forty feet, and in the pit the thickness exposed exceeded (in 1872) a depth of fifty feet vertical and yet the underlying trap rock was not reached. In the well section the rock is not so clearly shown from the smaller size of the opening, but in the quarry the unweathered surface of the walls shows the rock to great advantage. The rock is very different in character from the summit bed or water-shed series. Instead of being vertically tubulated or nearly horizontally disposed, this iron-clay consists of an aggregate of nodular fragments in a quasi-conglomeratic mass, the quasi-pebbles being arranged in rudely horizontal lines. Beyond these lines there are no traces of bedding, but the downward decrease of the percentage of iron in the rock is very clearly shown. No traces of any enclosed mineral of pre-trappean origin are to be found. The whole formation appears to be a sub-aërial accumulation of pluvial detritus of older iron-clay beds. The iron-clay exposed in ballast pits close to the reservoir north of the pit and close to the post office and *Idgáh* is truly vesicular and far more ferruginous. No sections showing the relations between the vesicular iron-clay of the pit and the nodular rock are exposed in the hollow east of the cantonment or in the church hill. Both varieties are much covered by thick red sandy soil which is so largely developed over both iron-clay and trap and gneiss, and in places is so much charged with nodular pieces of iron-clay that it is often impossible to draw any line showing the true boundary of the trap and the older iron-clay and gneiss.

Sedimentary. Iron-Clay.

Beds of iron-clay strongly resembling the typical iron-clay beds are found as outliers of the trap area. In most cases they were probably once continuous with iron-clay beds belonging to the Deccan trap series.

The iron-clay plateau, the boundary between the Belgaum and Kánara districts, extends from Gausi southward up the slope of the eastern spur of the Darshnidongar in North Kánara. The iron-clay[1] resting upon and passing down into the weathered surface of the underlying gneiss is continued along the ridge to the very summit of the mountain where it is cut short by a sudden scarp. This scarp trends from the summit to the east on both sides of the ridge, the northern scarp joining the west scarp of the main mass of the Gausi plateau, and the southern scarp running east by south of Mendil and ending in a bluff to the east of Degaon. The passage of the base of the iron-clay into the lower gneiss is clearly seen in various sections in the scarped edges of the iron-clay plateau, in the beds of the streamlet near Gausi, and in the stream that flows west from Talevádi. In these beds the descent from the pure iron-clay into decomposing gneiss is clear, the quartzose laminæ remaining after the softer parts have been replaced by the clayey mass. In the small stream that rises south-west of Mendil south of Talevádi, the upward passage of a micaceous schistose gneiss into iron-clay is very clear. The iron clay is frequently a breccia in structure owing to the presence of numerous small angular fragments of white vein quartz which are very frequently seen in similar iron-clays far away from the gneiss rocks and wholly of trappean origin.

A small and well-marked iron-clay plateau, twenty to thirty feet thick, forms an outlier on the top of the Bidarbhávi hill five miles south-east of Yellurgad. It shows much vertically tubular structure, and the amount of iron contained decreases speedily with the depth. The rock is also very distinctly bedded. Below the base of the scarp no rock is satisfactorily seen in place; but the sides of the hill are covered with broken iron-clay or masses doubtfully in place. Nor is the gneiss exposed for some distance from the base of the hill, the nearest visible portion of Deccan trap being the south spur of Yellurgad. From its external resemblance, as compared with Yellurgad, it probably represents an altered inter-trappean or infra-trappean deposit.

Tertiary Deposits.

Of later tertiary and alluvial deposits there are three; fresh-water sedimentary rocks, fossil-bearing river rocks, and old and new river alluvia. Of these the most noticeable are the fossil-bearing river rocks under a covering of black clay. They are of dark brownish-black stiff clay with partings and thin beds of gritty or sandy clay. The fossil-bearing beds are shown in the banks of a stream that flows into the Ghatprabha at Chikdauli, three miles north-east of Gokák. At the point where the bones were found[2] the section is, (4) regur or

[1] Though, as seen from the north, from various points along the Jámboti ridges or from the lower iron-clay terraces of Ambgaon and Chapoli, the Gausi plateau strongly resembles a normal iron-clay capped trap area, no positive trace of the Deccan trap was found by Mr. Foote.

[2] Of the fossils the most interesting is an extinct species of rhinoceros. A number

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cotton-soil passing into (3) black clay which contained the head of a rhinoceros, (2) clayey grit, two beds with clayey parting and numerous specimens of *Unio* and *Corbicula* in the gritty bands, and (1) reddish-brown black clay with bovine remains.[1] The bones are in a friable state, somewhat distorted by pressure, and much comminuted or broken by the action of numerous shrinkage cracks in the clay. Some of the bones are much encrusted by chalky deposits.

Alluvial Basins.

The alluvia of the several rivers agree very closely in character. They consist almost entirely of alluvial regur or black soil, with some beds of sand and gravel, frequently cemented by limestone nodules into coarse conglomerate. On the smaller rivers the alluvium in some cases is confined to a well-marked flat surrounded by higher grounds. Four cases of this kind are noted on the Ghatprabha and its tributaries, and in each of the four the alluvial flat or basin lies above a narrow gorge through which the river forces its way. Two of these alluvial areas occur, and both occupy shallow valleys above the eastern edge of the trap hill region. The one occurs along the course of the Márkándeya, some two miles north of Belgaum, and the other along a stream that rises in the Yellurgad hill and joins with those that drain the Belgaum downs. Both end abruptly eastward by the streams entering narrow gorges in the quartzite hills, and in both cases the alluvium is a black clay or a quasi regur.

A third basin to the south of Páchápur is at the meeting of the Márkándeya and the Belgaum river. The black regur-like alluvium in the upper part of the flat contains much nodular limestone. The lower part is wholly covered by thick regur, but in the upper parts between Ankalgi and Hudali there is a great development of pale-reddish and yellowish sandy loam with much limestone in filtration, strongly resembling the tertiary deposit known as loess, which forms steep cliff-like banks twenty-five to thirty feet high.

The fourth alluvial basin begins immediately below Gokák and stretches nearly eleven miles north-east to Tegdi. The lower part of the basin is hidden by a thick covering of cotton-soil through which only one section penetrates. The bone-bearing beds under the regur, which are exposed only in the Chikdauli stream are dark coloured clays with gritty clayey sands, and contain mammalian bones and fresh water shells. The space between is completely masked by cotton soil. It is probable that the Gokák basin joins the alluvial deposit which fills the valley of the Kelvi, a tributary of the Ghatprabha from the south. These alluvial deposits are gravels and coarse loam, the latter resembling the loam of the Belgaum stream at Hudli. These gravels rest on the various older formations that form the bottom and sides of the old valley, namely the gneiss, quartzites, Deccan trap, and inter-trappean beds. The gravel is in

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of bones were found loose in the bed of the stream, and others were obtained in 1871 by digging in the fields. Many of these are bovine and a few belong to a smaller specimen of Rhinoceros deccanensis, the nasal bones of which were not found. The specimen was just adult, and from the absence or very small size of the incisors the animal had probably a large horn.

[1] The bovine animal was in the shape of its molars nearly allied to the bison Gavæus gaurus which still inhabits the thickly-wooded slopes of the Sahyádris.

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Alluvial Basins.

great part sub-angular and contains pebbles of all the older rocks that occur in the neighbourhood. The gravels or loam have no organic remains.

The river alluvia consist very largely of regur or cotton soil partly washed up by the river action and partly washed down by rain action from higher grounds. In many cases this reguroid alluvium is undistinguishable from the true regur, as it in great measure assumes the same character if broken by innumerable sun cracks, by which in time the laminated structure due to its sedimentary origin is wholly lost.

Gravel beds of two classes are found, one of them river deposits the other lake deposits. Almost all the larger Karnátak rivers have on their banks deposits of gravel and shingle sixty to eighty feet above ordinary flood level. These shingle beds, there can be little doubt, are relics of the time when the spurs of hills through which the river channels are now cut were barriers that dammed back the river waters into lakes. Of these high level gravel beds the only case noted within Belgaum limits is on the Malprabha, nine miles west of Saundatti. Gravel beds, probably of lake or river origin, are found along the foot of the Kathárigad hills near the village of Tolur, about eight miles north-west of Manoli. In the Tolur bed, though not in such quantity as in some beds near Bádámi, rather water-worn chipped stone tools have been found lying on the surface.

Sub-Aërial Formations.

The reproductive action of open-air influences have produced five formations. Of the iron-clay, which is the chief of these open-air formations details have already been given. The others are (1) conglomerates formed mechanically by the deposition of clay and iron cements; (2) deposits cemented by the chemical precipitation of calcareous matter; (3) pluvial or rain rain caused aggregations; and (4) blown sand.

Cases of the cementing of the remains of the lower Kaládgi quartzites by the deposition of iron-clay are noticed at Somápur a little south-east of Kathárigad, and three miles further west on the plateau east of Murgod. At these places numerous large quartzite pebbles weathered out of sandstone conglomerate have been recemented in very nearly their original position. The new rock looks much like an artificial pavement. A very similar, but even more striking effect, is produced by the cementing of rounded quartzite fragments in the valley south-west of Tumurgudi about eleven miles north-east of Belgaum. This pavement stretches for several hundred yards.

A case of cementation of angular fragments of gritty quartzite into a breccia by the introduction of a red sandy cement is observed in the saddle between the north-east side of One Tree Hill at Belgaum and the south-east corner of the quartzite plateau to the north-east. This breccia might, from its position, be easily mistaken for part of the lower Kaládgi quartzites, the coarse pebbly basement beds of which are exposed close by and seem to rest on highly upturned micaceous schistose beds in a section a little to the north-east of Kanburgi. Instances of the formation of small patches of sub-aërial conglomerates and breccias by the lateritoid decomposition of ferruginous rocks are very common.